ARBETSRAPPORT 1020-2019 (English version)

Decision support for proposing main extraction routes in final felling

DEMONSTRATION REPORT: SÖDRA

PHOTO: ARON DAVIDSSON/SKOGFORSK

skogforsk

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Summary

Beslutsstöd för förslag till huvudbasvägar i slutavverkning

Demonstrationsrapport Södra Skogsägarna

Skogforsk har under flera år utvecklat och utvärderat modeller för förslag till basvägs-dragningar. Modellerna bygger på optimeringsalgoritmer och indata från detaljerad digital information om topografi, virkesvolymer samt markfuktighet.

Modellerna visar lovande resultat, men då flera justeringar av indata sker i fält finns behov av att utvärdera hur väl en mobil applikation skulle fungera. Modellerna behöver även testas i mer utmanande terränger och mer kuperade områden.

Syftet med projektet var att effektivisera den skogliga planeringen genom att ta fram och utvärdera förslag på basvägsdragningar i fält i en mobil applikation. Målet var att genomföra utvärderingar av den mobila lösningen vid tre av Södras verksamhets-områden: Linköping, Sollebrunn och Växjö. Därutöver utvärderades möjligheten att föreslå lämpliga avläggspunkter i förväg baserat på olika geodata.

En mobil applikation för basvägsplanering utvecklades och under hösten 2018 genom-fördes tester på 103 trakter. Återkoppling samlades in för 84 av trakterna (28 trakter i Linköping, 23 i Sollebrunn och 33 i Växjö). I alla områden genomfördes testerna av både inspektorer och produktionsledare. Det som kontrollerades var den egna planeringen före avverkning samt under och efter pågående drivning. Oftast fokuserades på större trakter (> 4 ha) där det fanns möjlighet till alternativa vägval. För trakterna testades också att variera optimeringsalgoritmens känslighet för lutning och markfuktighet.

Basvägsförslaget bedömdes användbart på 73 av de 84 trakterna med återkoppling (87 procent). Den uppskattade tidsbesparingen visade att det i 60 procent av fallen fanns en tidsbesparing i planeringsdelen.

Sammantaget är utvärderingen positiv och ett gott beslutsunderlag för vidare beslut om implementering i Södras systemstöd samt vidare FoI-arbete kring denna typ av beslutsstöd.

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Foreword

In this project, a mobile application that generates proposals for main extraction routes was developed and evaluated.

The project received funding from the EU as part of the Efforte project[1]. We would like to thank many committed employees of Södra who carried out the evaluation. The project manager at Södra was Joel Persson. Skogforsk was responsible for project management and method development and evaluation, and Creative Optimization AB developed the mobile application.

We also wish to extend warm thanks to everyone who supported the project through their interest and qualified input.

Uppsala, June 2019

Erik Willén, Aron Davidsson, Mikael Frisk, Patrik Flisberg, Mikael Rönnqvist

[1] The project received funding from Bio Based Industries Joint Undertaking within the European Union's Horizon 2020 research and innovation programme, Grant Agreement No. 720712 with a project duration: 1.9.2016 - 30.8.2019. Coordinator: Natural Resources Institute Finland (Luke).

Contents

Summary

For several years, Skogforsk has been developing and evaluating models that generate proposals for main extraction routes. The models are based on optimisation algorithms and input data from detailed digital information about topography, wood volumes and soil moisture. The models show promising results but, as the input data is adjusted in the field, there is a need to evaluate how well a mobile application would work. There is also a need to test the models in more challenging terrain, such as sites with steeper gradients.

The aim of the project was to improve the efficiency of forestry planning, by developing and evaluating proposals for main extraction routes in the field, generated by a mobile application. The mobile solution was to be evaluated in three of Södra's production areas: Linköping, Sollebrunn and Växjö. The ability of the application to propose suitable landing sites in advance, based on various geodata, was also evaluated.

A mobile application for planning main extraction routes was developed, and tests were conducted on 103 harvest sites in autumn 2018. Feedback was collected from 84 of the sites (28 in Linköping, 23 in Sollebrunn and 33 in Växjö). In all the areas, the tests were conducted by both inspectors and production managers. The tests comprised checking the planning before harvest, and during and after logging. The focus was usually on larger sites (>4 ha), where various extraction routes were possible. Tests were carried out that involved varying the optimisation algorithm's sensitivity for slope and soil moisture.

Of the 84 sites with feedback, the proposal for main extraction route was deemed viable on 73 (87%). The estimated time savings showed that planning time was shortened in 60% of the cases.

The experiences and results were summarised in a joint project workshop, and the following observations were made:

1. Errors in the depth-to-water (DTW) map can negatively affect proposals for the main extraction route, because the DTW map provides part of the information used in the optimisation.
2. The proposals often correspond well with the choices made by the inspectors and contractors. The proposal can reduce the need to visit harvest sites.
3. A positive feature is that the proposal considers wood volume variations in the harvest sites.
4. Positive with new ('outside the box') proposals that could reduce costs for forwarding, not necessarily using older main extraction routes.
5. The tool can be a support in planning, particularly where new employees were involved or when the planning involved new areas.
6. The tool is useful when logging is started in darkness or under conditions of snow cover.
7. The tool can help to meet the need to harvest and forward wood all year round.
8. The best areas of application were felt to be in commercial thinnings (with no existing main extraction routes) or in final fellings with longer forwarding distances.
9. The tool has great potential for use in contract discussions with landowners.

Overall, a positive evaluation; a good decision support tool that can be considered for implementation in Södra's system support and that provides a good platform for further R&I on this type of decision support.

Background

In recent years, increasing attention has been drawn to issues regarding soil and water, and the forestry sector has used various methods to try to reduce the impact on water by minimising damage caused by harvesters. A common environmental policy to minimise soil damage on forest land has been drawn up in the sector, providing examples of good practice and classifying different types of damage (Berg et al., 2010).

Studies show that ruts caused by harvesters are concentrated to moist and wet soils, while damage on dry and healthy soils is limited (Bergkvist et al., 2014; Friberg et al., 2016). Soil damage can be reduced by concentrating log extraction to areas with better bearing capacity, and through various measures such as placing slash from trees (tops and branches) on the ground and building crossings over wet areas and sensitive sections.

The national digital elevation model developed by Lantmäteriet (the Swedish mapping authority), created through laser scanning, has meant a breakthrough for forestry planning. The opportunity to both cost-effectively create precise digital terrain models and describe height and volume variations in the stand at high resolution brings considerable advantages.

The DTW maps, developed by the University of New Brunswick (Bergkvist et al., 2014; Murphy et al. 2009), model the depth to the groundwater from the surface, using height and slope conditions in the terrain in relation to the surrounding terrain, and have proved very important (Figure 1). Skogforsk has used and refined the method.

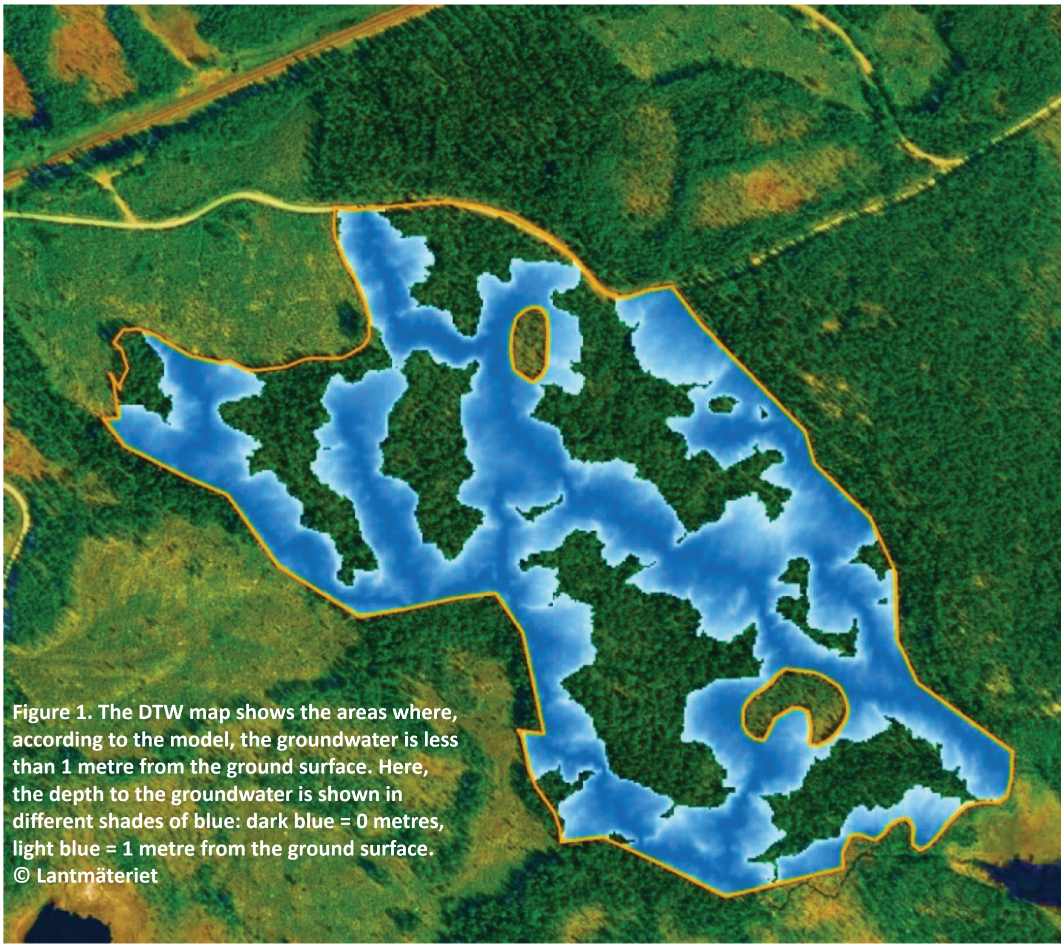

Figure 1. The DTW map shows the areas where, according to the model, the groundwater is less than 1 metre from the ground surface. Here, the depth to the groundwater is shown in different shades of blue: dark blue = 0 metres, light blue = 1 metre from the ground surface. © Lantmäteriet

Evaluations have shown that the DTW maps have great potential to reduce the number of serious incidents of ground damage caused by forest machines (Friberg et al., 2016). The classes of soil moisture on the maps correspond well with field surveys (Bergkvist et al., 2014).

New research shows potential to further develop the DTW map, and also to detect many more watercourses in forests (Lidberg, 2019). Greater knowledge about these can help reduce the number of serious incidents of ground damage during felling.

Since 2014, Skogforsk has been developing a tool, BestWay, which generates proposals for main extraction routes from landings and out over the planned harvest site (Figure 2). The proposal is based on input data provided by the user about the harvest site boundaries and landings. Unavoidable routes can be entered in the tool, such as crossing points over streams or a predetermined route between the landing and the harvest site. The tool then carries out an optimisation based on a digital terrain model, the DTW map, wood volume estimation, and various retention areas for preserving natural and cultural values. The method is summarised in Willén, et al., 2017a.

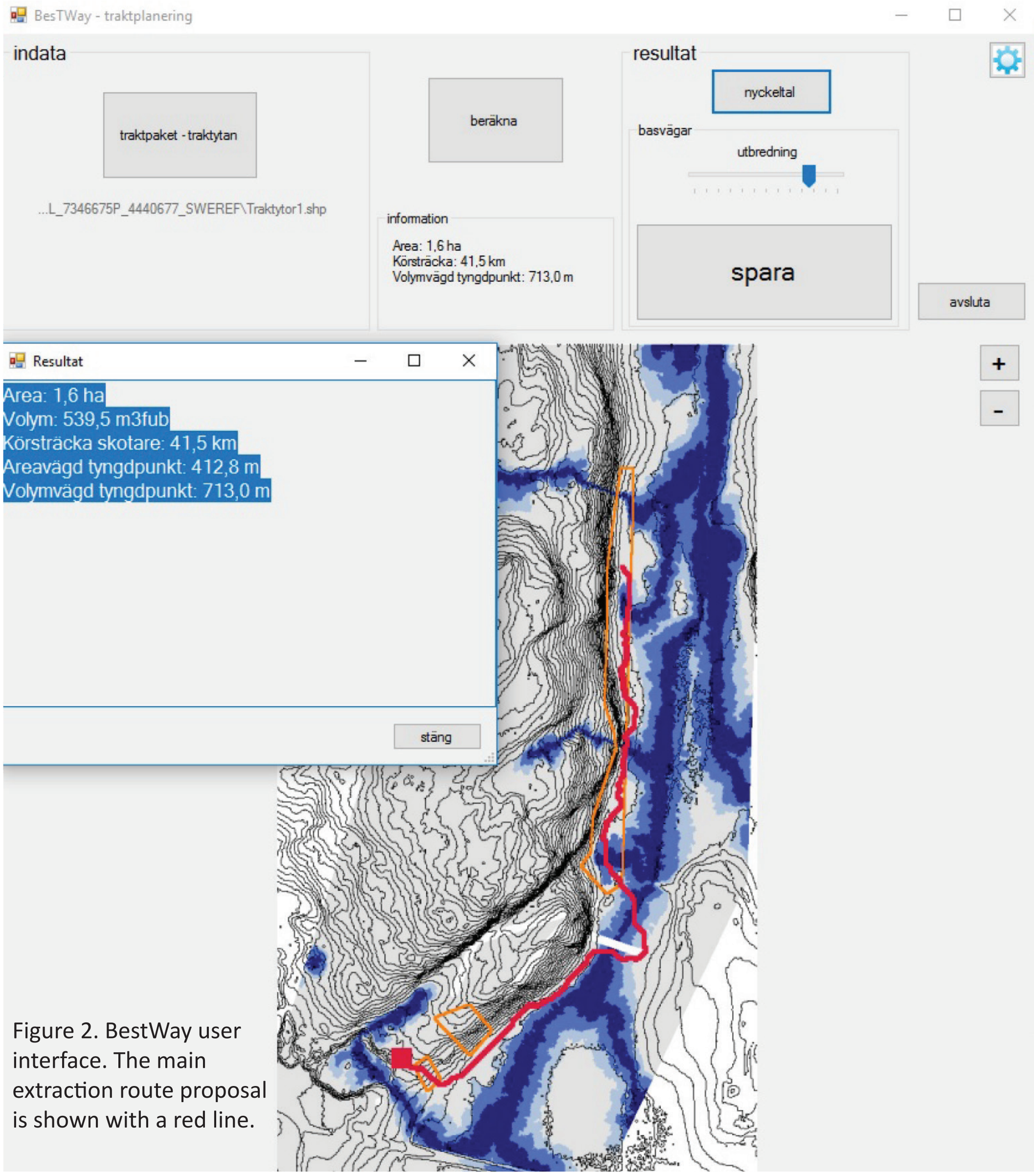

Figure 2. BestWay user interface. The main extraction route proposal is shown with a red line.

The tool has since been evaluated in production areas of BillerudKorsnäs, Mellanskog and Södra (Willén et al., 2017b,c). The evaluations showed that the tool works well for harvest sites larger than 2-3 hectares, assuming the landing is well placed. Several advantages were identified, e.g. the machine teams are given a good proposal for where the harvest site starts, a more objective measure of mean forwarding distance, and shorter total forwarding distance. Suggested improvements included using the tool to propose suitable landing sites and adapting it for field use in a mobile application.

Aims and objectives

The aim of the project was to improve the efficiency of operational planning, by developing and evaluating proposals for main extraction routes in the field, generated by a mobile application. The objective was to evaluate the mobile solution in three of Södra's production areas: Linköping, Sollebrunn and Växjö. The ability of the application to propose suitable landing sites in advance, based on various geodata, was also evaluated.

Material och methods

INPUT DATA

The study area used in the project were three production areas of Södra skogsägarna, shown on Figure 3: Linköping (green), Sollebrunn (purple), and Växjö (blue).

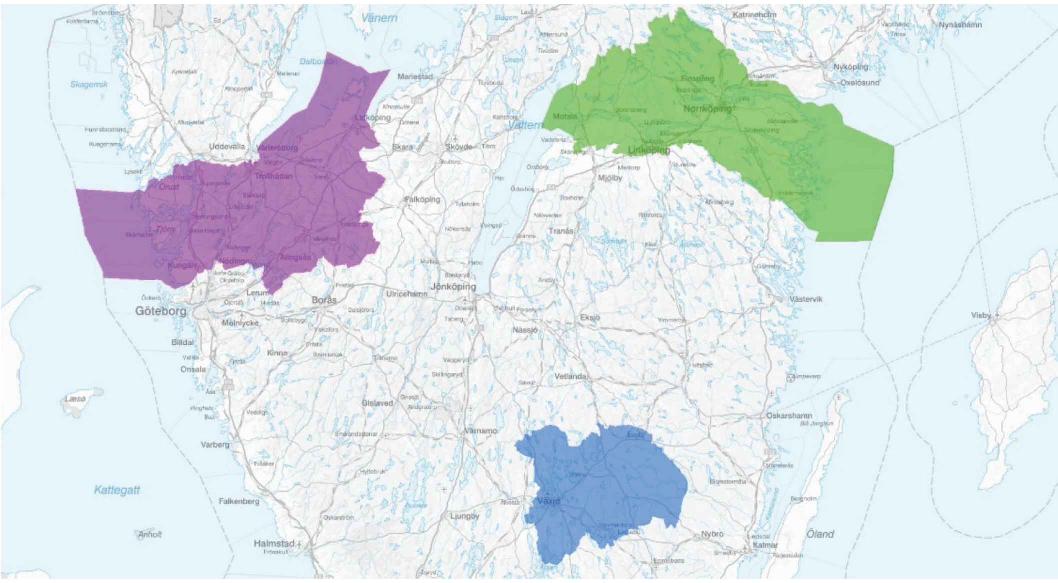

Figure 3. The three Södra production areas comprising the study area. © Lantmäteriet

Input data for the main extraction route proposals were:

- **Grid 2+**
  Height data from Lantmäteriet with 2-m spatial resolution (geoTIFF).
- **DTW map**
  Södra's DTW map of the study area was available with a continuous moisture scale, and was recoded into three moisture classes for use in BestWay (geoTIFF).
- **Forest volume estimations**
  Forest volumes from the National Forest Inventory (SLU) with wood volume estimations from laser data. The total volume was chosen, and a grid with a 12.5-m resolution was calculated (geoTIFF).
- **Retention areas**
  Retention areas for preserving natural, cultural and social values were designated 'No-Go' areas, and no main extraction routes could be drawn through these areas. Based on the retention layers used at Södra, No-Go areas were determined for each layer, and these were compiled into a common vector file, 'No-Go areas'. A list of retention layers is shown in Appendix 1.

The tool was then used for the harvest sites where final felling was to be planned. Data on stand boundaries and landings were retrieved from Södra's operational planning documentation.

Input data for the landing proposals were:

- National Road Database (NVDB), information on private roads from the relevant road owner.
- Property map
- Grid 2+
  Height data from Lantmäteriet with 2-m spatial resolution (geoTIFF).
- No-Go-areas

METHOD

Identification of main extraction route

Timbertrail, a field application developed for tablets (Ipad), is based on the same input data and similar methods as BestWay. It is used to identify optimal driving routes for forest machines in felling and forwarding. One very important feature is that the planner, directly in the field, can revise data that is incorrect and/or unreliable. For example, proposals for crossings over streams or very wet areas can be moved when the correct information about the situation is not available until the field visit.

The field application was developed by Creative Optimization, a company that commercialises research results, for example optimisation models for planning in the forestry supply chain. The application uses all available data sources, and uses an optimisation model to calculate how the extraction route should be placed to minimise the risk of soil damage and to improve the efficiency of planning and harvesting. If a field visit to the harvest area shows the need for adjustments in the basic data, this is simply done, and a new calculation made directly in the application in the field.

The user quickly obtains optimal proposals for the extraction route and information about mean (and total) transport distance. Basic data and other settings can be revised in the field before generating new optimised proposals, there is clear visualisation in the application's map, and the result can be sent to the machine computer.

The application allows editing of, for example, No-Go areas, crossings and landings. The user can also choose relative levels of weighting in the optimisation, such as DTW maps, slopes along the operational route, sideways inclination, soil moisture and driving within site boundaries.

BestWay uses the same data sources as Timbertrail to generate main extraction routes for the same problem. The field application is more user-friendly and solves the optimisation much faster.

Identification of landings

In order to identify suitable landings, a suitable landing must first be defined. The analysis is divided into two steps, the first of which identifies purely physical obstacles to landing placement, while the second identifies obstacles in the form of regulations or retention sites important for society and the environment.

- **Physical obstacles** (Table 1)
  These mainly comprise the terrain at the landing site. The ground needs to be relatively flat, so that the wood can be placed in regular and stable stacks. Sections that slope or contain a lot of rocks and stumps are less suitable as landings.
- **Obstacles created by regulations or retention sites important for society and the environment** (Table 2)
  These can be more difficult to categorise definitively, and may also vary between different sites and regions. Generally, these obstacles involve not placing wood too close to dwellings and villages, at road crossings where visibility could be made difficult for car drivers, or close to ditches and power lines. Landings should not be placed in various retention areas in forests and close to ancient antiquities or heritage sites. Many of these obstacles are already recorded in various geodata layers and, in this study, both grid data and vector data were used to ensure that as many such obstacles as possible were included.

The tables show the different obstacles considered in this study.

Table 1. Input data for physical obstacles.

Physical obstracles	Data type	Data source	Owner
Slope	Grid	Grid2+	Lantmäteriet

Table 2. Input data for obstacles resulting from regulations or retention sites important for society and the environment.

Obstacles resulting from retention sites important for society and the environment	Buffer type	Buffer size	Data type	Data source	Owner
Watercourse	Road crossing	6 m	Vector	Property map	Lantmäteriet
Power lines	Road crossing	6 m	Vector	Property map	Lantmäteriet
Type of ownership	Everything except deciduous forest, coniferous forest, grazing and open land	Entire area	Vector	Property map	Lantmäteriet
Facilities	All areas	Entire area	Vector	Property map	Lantmäteriet
Buildings	All areas	20 m	Vector	Property map	Lantmäteriet
Crossing	All road crossings for Road Class 7 downwards	30 m in all directions		National Road Database	Swedish Transport Administration
Site of high natural or cultural value		Entire area	Vector	BillerudKorsnäs, combined data layer for forest conservation	BillerudKorsnäs Bergvik Skog Swedish Forest Agency RAÄ

Road network

Possible sites for landings were identified alongside all private roads. Along the road network, small square sites were created along each side of the road, and their suitability as landings was categorised. Long sections of roads could then be evaluated in a structured and similar way, taking into consideration the conditions at the point where the logs would be placed.

The size of the area was defined by the perpendicular distance from the road needed to enable a forwarder to stand in front of the timber pile and unload the wood. Twelve metres from the roadside was deemed to be sufficient for the forwarder and wood stacks of ordinary assortments, and the 12-m squares were then created.

Model

The model, which was based on the input data regarding the private road network and the various obstacles, involved five steps. In this analysis, No-Go refers to unsuitable landing sites.

1. Along each road, on both sides, 12-m squares were created.
2. In each square, height values were recorded from Grid2+ and analysed. No height variations greater than 2 metres were permitted in the square, or height variations greater than 2 metres in relation to the height of the road. These were classified as No-Go on account of terrain deviation.
3. A No-Go layer in the vector format compiled the vectorised obstacles, identifying squares that were not suitable for landings.
4. The road squares remaining after step 2 were analysed with an overlay analysis against the No-Go layer with vectorised obstacles. If any of the landing squares were touched by the No-Go layer, these were removed and classified as No-Go on the grounds of vector data.
5. Remaining road squares were classed as approved squares for placement of landings.

The three categories:

- Approved landing zones
- No-Go terrain zones
- No-Go vector zones

At the northern end of the road (Figure 4) where there is a T-junction, No-Go vector squares can be seen, and such squares also occur in other sections of the road because of an ancient monument, a cultivated field and a power line. In the middle of the road section is a residential plot, which also generates No-Go vector zones. In the southern part of the road section, sporadic No-Go terrain zones can be seen that were created because the terrain does not meet the requirement of a maximum height difference of 2 metres. Other zones shown by the model can be regarded as approved for landing placement.

Figure 4. The colour codes show the classification given to each road zone after analysis with the obstacles. In the middle of the map, for example, a residential plot can be seen that generates a No-Go vector zone, and similar No-Go zones were generated near an ancient monument and a road junction in the north. In the southern part of the map, individual No-Go terrain zones can be seen where the requirement for a maximum height deviation of two metres was not satisfied.

Evaluation

The evaluation was carried out by inspectors and production managers from the three production areas. From each area, 3-5 people used and evaluated the application, with the aim of completing approximately ten harvest sites per month and person. The evaluation took place from September to November 2018 with continual reporting of tests carried out on the relevant sites, and a completed feedback questionnaire for each site. The feedback questionnaires were submitted every month. The feedback was structured according to Figure 5. All submitted data was compiled on a common storage space.

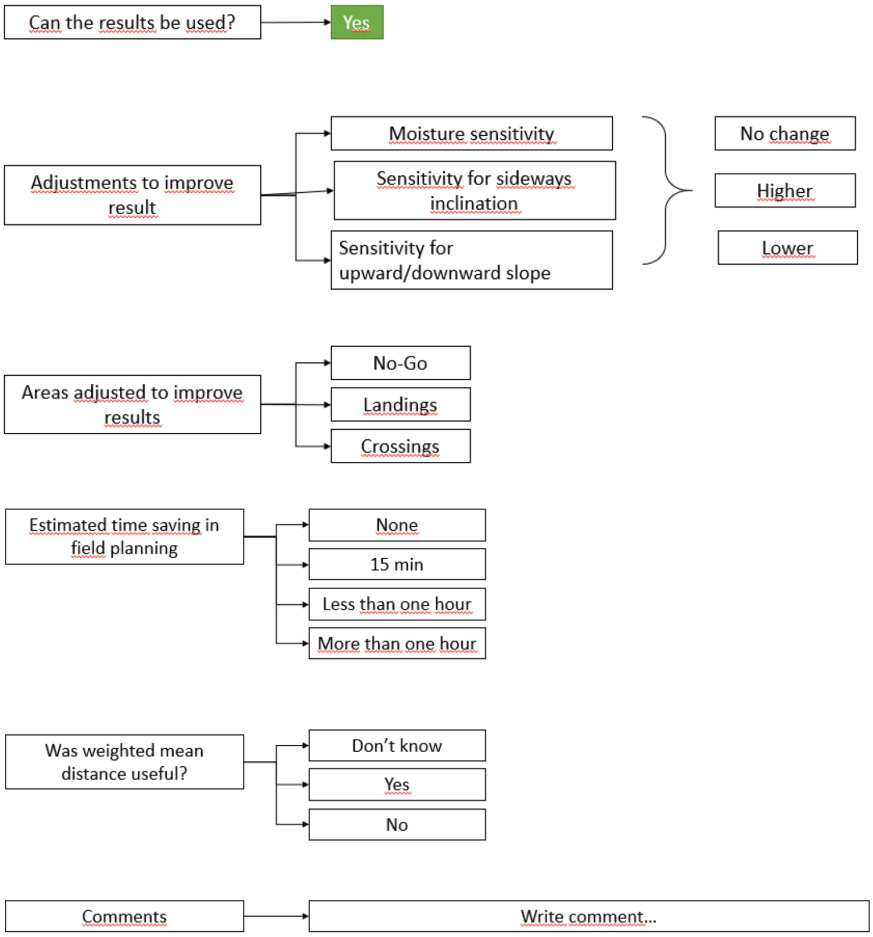

Figure 5. Feedback questionnaires in tests of Timbertrail.

The field trials were mainly carried out before felling, but in every production area an attempt was made to also include some harvested areas where the tool had not used been beforehand. This was to evaluate whether the main extraction route proposal was better than the actual routes used in the harvesting.

A final, concluding workshop summed up how the tool had been used and how it worked, and the results of the site-specific feedback were presented. The workshop focused on:

- Experiences and results from the tests
- User-friendliness in the field
- Other areas of use
- Ideas for implementation in the future

To evaluate landing identification, the proposed landings were used that were planned for the harvest sites and that were included in the evaluation of Timbertrail. These harvest sites included landings on public roads, private roads and tractor roads but, in this study, we had decided to focus on landings on private roads.

The proposed landings were placed in categories. Obstacles involving some form of retention, terrain where height variation on the site or height difference compared to the road was too great and, finally, approved sites where none of these other parameters occurred.

Results and discussion

FIELD APPLICATION

The following shows three examples of the results from Timbertrail. The application comprises a map part and an information part. The map part shows main extraction routes and strip roads radiating out from a selected landing. The information part shows which input data was used, site properties, information about the total strip road length, the total forwarding length, and weighted forwarding distance and mean forwarding distance.

Figure 6 shows a site from Linköping. The site is relatively large, 18.2 hectares, and two landings have been proposed, one in the southern part and the other in the north. The mean forwarding distance varied greatly, according to whether or not the distance was weighted with wood volume (493.3 or 306.2 metres).

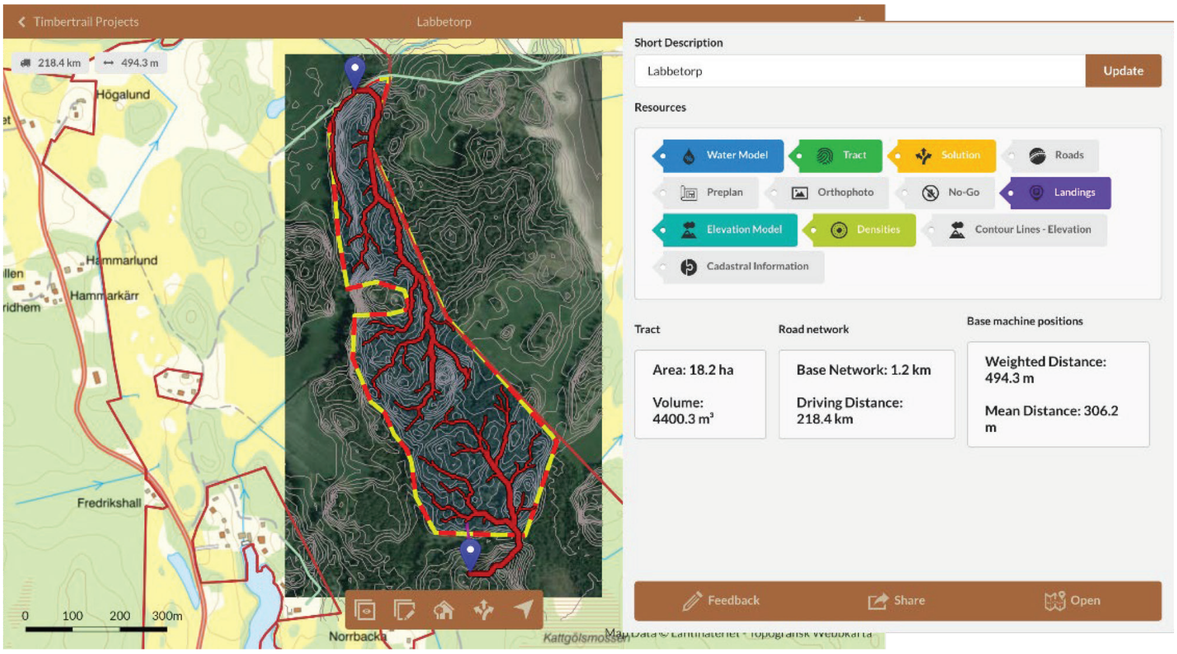

Figure 6. Results from a site with two landings in the Linköping production area.

In Figure 7, the same site is shown as in Figure 6, but this time only showing one landing, in the northern part. The result for the site shows a similar proposal for the main extraction route. When there is only one landing, the total main extraction route length falls from 1.2 km to 1.1 km, but the total driving distance increases from 218.4 km to 339.3 km.

If we consider differences in mean forwarding distance, the volume-weighted distance increases from 493.3 to 764 metres, and the non-volume-weighted from 306.2 to 579.9 metres. In this case, two landings are worthwhile in terms of logging costs, and shows that one area of use for this type of application is in comparing different proposals.

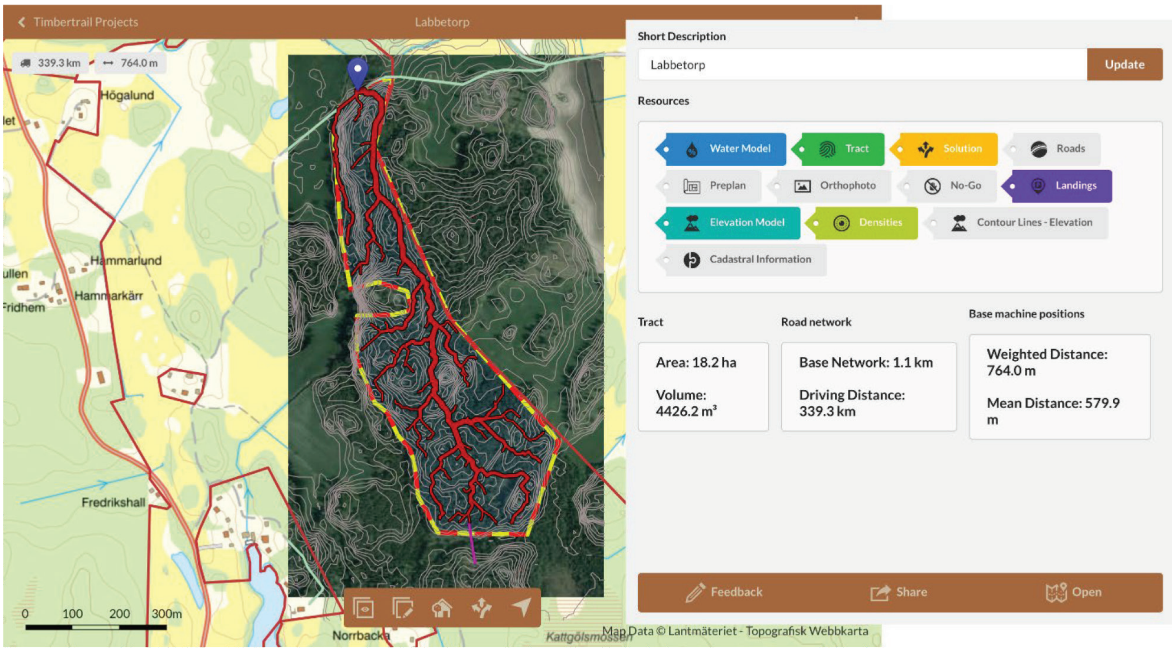

Figure 7. Results from a site with one landing in the Linköping production area.

Figure 8 shows a site from Sollebrunn. The site is relatively large, 17.8 ha, and only one landing was used, which gave a long mean forwarding distance, volume-weighted, of 442.6 metres.

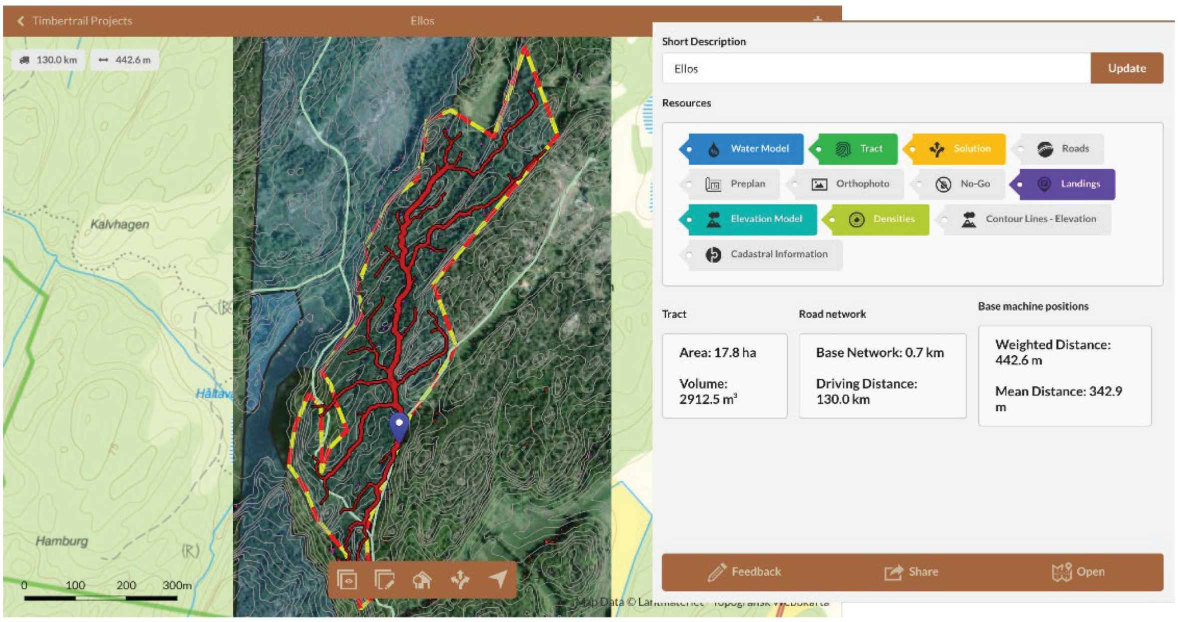

Figure 8. Results from a site in the Sollebrunn production area.

EVALUATION

In autumn 2018 , tests were carried out on 103 sites, and feedback collected from 84 of them. Twenty-eight of the sites were in Linköping, 23 in Sollebrunn, and 33 in Växjö. In all the areas, the tests were conducted by both inspectors and production managers. The tests comprised checking the planning before harvest, and during and after the logging. The focus was usually on larger sites (> approx. 4 ha), where alternative route options were possible. Tests were carried out that involved varying sensitivity for slope and soil moisture.

Of the 84 sites with feedback, the main extraction route proposal was deemed viable on 73 sites (87%). The main reasons why the route proposal was not deemed viable were:

- A simple planning procedure (usually small sites) where a main extraction route proposal was not necessary
- Too much of a detour
- Too much of the main extraction route was already predetermined
- The main extraction route proposal involved steep sections

During the tests, adjustments were made involving different landings, new retention areas (where no main extraction routes could be drawn), new crossings, and moisture sensitivity (varying resistance settings for soil moisture class).

Analysis of time savings showed that time was saved in the planning stage for 60% of the cases (Figure 9), assuming that the tool was implemented in Södra's system environment. It is important to emphasise that most tests were carried out on slightly larger sites or sites that were more difficult to plan, which makes it difficult to directly scale up the figures to apply to the entire organisation.

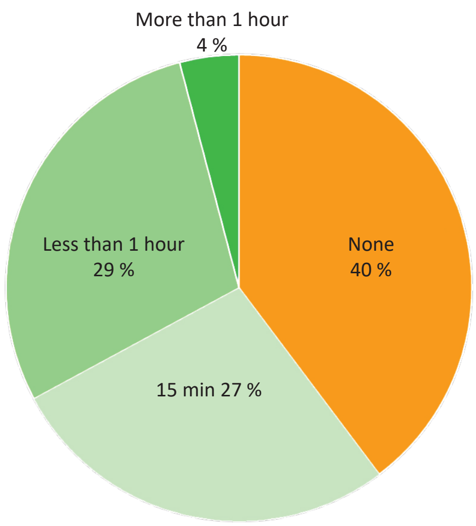

Figure 9. Estimated time savings after using the tool.

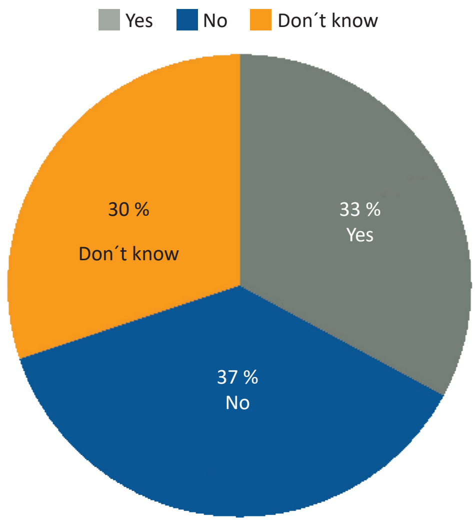

Figure 10. Was the weighted measure on mean forwarding distance useful

The weighted mean forwarding distance could be used on one-third of the sites (Figure 10). Here, too, site size and planning complexity naturally affect the result.

The free-text comments submitted also gave good feedback on how the tool worked:

1. “It was interesting that, when the sensitivity for water was changed to strong, the app then selected the southern landing, which was approximately 400 m further away, to avoid driving over grazing land. This can be worth bearing in mind when logging in a period of poor bearing capacity.”
2. ”Very difficult terrain, the proposal corresponds well with the existing main extraction route. Have tested two landings. The landing at a short distance would require roadworks before it could be used. The difference in mean forwarding distance gives a rough estimate of added value in monetary terms. This will be a subject for discussion with LO[2] ”
3. ”In a check after felling, the app’s route choice was in many cases better than that chosen by the contractor. If they’d had access to the information, the result could have been much better.”
4. ”Resolution in terrain data too poor (main extraction route placed in sloping sections)”
5. ”The landowner has previously had an existing main extraction route south of the proposed route that passes through a wet area. The landowner should consider moving the existing main extraction route to the proposed one.”
6. ”Corresponds well, saved time for the contractor.”
7. ”Used to follow up rutting after completed harvest. Showed alternative routes to those the thinning team chose to use, stimulating discussion about how this could have been avoided.”
8. ”Used to compare landings. The app chose to draw half of the wood to each of the landings, which was incorporated in planning of future felling.”

Many of the free-text comments showed the benefit of information that could be discussed with the landowner, but also benefits for the contractor in connection with start-up or during logging, by proposing shorter forwarding distances or more landings. The possibility for use as a follow-up tool after logging in collaboration with the contractors was another benefit identified.

[2] LO = landowner

Summary of experiences reported in the workshop:

1. Errors in the DTW map can negatively affect proposals for the main extraction route, because the DTW map provides part of the information used in the optimisation.
2. The proposals often correspond well with the choices made by the inspectors and contractors. The proposal can reduce the need to visit harvest sites.
3. Positive that the proposal considers wood volume variations.
4. Positive with new ('outside the box') proposals that could reduce costs for forwarding, and not necessarily using older main extraction routes.
5. The tool can be a support in planning, particularly where new employees are involved or when the planning involves new areas.
6. The tool is useful when logging is started in darkness or under conditions of snow cover.
7. The tool can help to meet the need for logging all year round.
8. The best areas of application were felt to be in commercial thinnings (with no existing main extraction routes) or in final fellings with longer forwarding distances.
9. The tool has great potential for use in contract discussions with landowners. For example, in discussions regarding alternative landings for more efficient felling and road transport.

The tool was found to be effective, fast and simple in terms of practical use in the field. One aspect that was less successful was the procedure of saving the results from the tests that were outside the ordinary flow of digital information about the site.

The calculated mean forwarding distance corresponded better than that produced by normal methods, but the distances were assessed to be slightly too short. At the same time, it is important to relate an optimally calculated forwarding distance with the actual distance in practice.

Other areas of use for the tool that were noted:

1. The function in the tool can help identify landings with limited storage volume where there is need to prioritise rapid removal by road, and a certain volume can be matched with the area of the landing.
2. Refine the model for planning of thinning; the model should both be able to indicate a main extraction route but also the strip road network according to the companies' thinning instructions.
3. In operational planning, with certain adjustments, the model can be used as a tool for strategic analysis.
4. Optimise selective measures in cases of special logging, such as logging to limit bark beetle damage and after storm damage. Create an optimal route for the areas in questions (selective sites).
5. Landing analysis; identify suitable and optimal placements for landings.

Ahead of any future introduction, the need was identified for the tool to be fully integrated in existing company systems, both in planning of logging and to enable contractors to make adjustments in connection with logging. This would enable changes to be made, for example, where circumstances change, such as a late change in harvesting area or weather (increased or reduced soil moisture).

IDENTIFICATION OF LANDINGS

To evaluate the landing identification, the proposed landings chosen for the harvest sites and those included in the evaluation of Timbertrail were used (Table 3).

Seventy-five landings placed along private roads were analysed. Landings were most successfully identified in Växjö, with an accuracy of 83% followed by Linköping (56%) and finally Sollebrunn with 27%. The total accuracy percentage for all three was 57%. Earlier tests with landing identification have shown a higher accuracy percentage, between 70 and 80 procent[3].

The main reason for the poorer result in Sollebrunn is the topography, as the site is very undulating. It is hard to find suitable sites with gradients lower than the defined specifications, which is shown in our evaluation. It is also necessary to use arable land in this area. Växjö is a relatively flat area, where it is easier to find suitable landing sites, which is also shown in our results.

[3] https://www.skogforsk.se/kunskap/kunskapsbanken/2018/ny-gis-modell-placerar-avlaggen-ratt/

Table 3. Analysis of landings in Södra's three production areas. The 'Accuracy' column shows the percentage of approved landings on private roads.

Total	Public road	Tractor road	Private road	Approved	Obstacles	Terrain	Accuracy
20	3	8	9	5	2	2	56 %
55	9	10	36	30	5	1	83 %
48	2	16	30	8	11	11	27 %
123	**14**	**34**	**75**	**43**	**18**	**14**	**57 %**

REFINEMENT OF MAIN EXTRACTION ROUTE PROPOSALS

The following suggestions for refinement were noted during the project:

- A structured evaluation of the adjustable slope parameters and how these settings affect the placement of main extraction routes in practice.
- Identify and document how regional deviations should be managed.
- More in-depth evaluation of forwarding distance and comparisons with alternative methods currently used in practice.
- Include landings in the optimisation proposal to make the overall proposals more complete. It is also important to further develop regional requirements to identify suitable landing sites.
- Evaluate the functionality in first thinnings when other main extraction route alternatives are lacking.

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Appendix 1. Retention layer, Södra

Retention layer	No-Go Area	Comments
SEPA_*Culture reserve*	No	Remove
National parks	No	SEPA - remove
Natura 2000	No	SEPA
Nature reserve	Yes	SEPA
Conservation area	No	SEPA - Forestry OK - Consultation
Monuments, SNHB lines	Yes	Uncertain positions, buffer 5 m
Monuments, SNHB points	Yes	Uncertain positions, buffer 5 m
Monuments, SNHB areas	No	Uncertain positions, buffer 5 m
Prot. Habitat protection	Yes	
Prot. Conservation	No	Conservation site - Consultation
Prot. Conservation Agreement	Yes	
Prot. ForestHist lines	Yes	Uncertain positions, buffer 5 m
Prot. ForestHist areas	No	Uncertain positions, buffer 5 m
Prot. ForestHist point	Yes	Uncertain positions, buffer 5 m
Prot. Fen forest	No	Large areas - Consultation 1+2
Prot. Key habitat	Yes	
Södra NS, NO	No	